ELECTRIC ELEVATORS

WITH DETAILED DESCRIPTION OF
SPECIAL TYPES

BY

FRANK J. SPRAGUE

SPRAGUE ELECTRIC COMPANY

NEW YORK CHICAGO

(c. 1900's)

ELECTRIC ELEVATORS.

There has been so much written on the subject of electric elevators which is pertinent to the subject, that in presenting this paper I shall make free compilation from others, and, supplementing these extracts with some new matter, I shall by lantern views illustrate some details of the more recent machines, their methods of manufacture, and some steps in their development.

The time has passed when any one can doubt that one of the most important applications of the electric transmission of power, and one in the number and variety of its applications already rivaling the electric railway work which has made such marvelous strides in the past eight years, is that of the operation of all classes of hoisting machinery..

Some idea of the extent of the present elevator business may be gathered from the fact that in New York City alone there are not less than 5,000 elevators of various kinds, more, in fact, than there are street cars, and more people are carried vertically than there are horizontally.

Ignoring for the moment the specific methods of application, and discounting the difficulties naturally met in developing machines to do the duty required in modern office work, not alone the technical difficulties, but those commercial ones naturally met when a new company enters the lists with untried machines against the entrenched forces of existing industries, there was still much of encouragement to be derived from a backward glance at the industrial changes wrought in the last few years, and to all objections raised there came the natural queries: Is the elevator field, great as it already is, limited to the possible application of a water or steam motor? Is there no wider, no more universal application of power for this class of service than has hitherto been presented? Is the hydraulic elevator the one bulwark to stand up against the assaults of the electric giant? Does it present such fixity of design, unity of purpose, refinement of processes, economy of operation and freedom from accidents as to preclude the improvement of using some other power?

Let us look at the record in other fields and ask: Why has the trolley system, born only eight years ago, driven the horse from the street? It involves great initial expense, the conversion, distribution and reconversion of energy. It faced all the powers of conservatism, ridicule and fear. It had to combat the allied forces of the Bell telephone interests tested by court action in over twenty States. It had the opposition of the strongest municipal and corporate influences. Every detail of the system had to be created, and yet it stands to-day unrivalled in its industrial progress.

Why is the same trolley system driving the cable to the wall, and why has its adoption marked the abandonment of a plant costing not less than $3,000,000, in the city of Philadelphia? Are there many examples of the more direct applications of force than the cable system, many closer connections between a great engine built for the highest economy and that which it moves?

Why is the steam locomotive giving way to the electric motor on suburban service? Is there any more direct example of the application of steam than is presented by a locomotive, the power of whose cylinders is transmitted directly to the drawbar through the intermediary only of a crank?

Why does the best shop practice dictate the abandonment of the slow speed highly economical Corliss engine and the direct application of power by belts and shafting, and adopt the high speed engine and direct-connected dynamo at a central station, with the conversion, distribution and reconversion of energy by a dozen different motors at a greatly increased initial expense? Is it for any other reason than convenience, reliability and economy of operation?

Why has every overhead crane builder in the United States within the past four years absolutely abandoned wire rope, square shaft and hydraulic transmission for the three-motor transmission which I advocated only nine years ago? It is because it is simpler, because it will cost less, or because it is more economical, more flexible, and because it answers the purposes better than the other and more direct systems?

Why have the great central stations of the country adopted electricity for the transmission of power to the hundreds of industries within the radius of their supply, and into what form of energy is the power of Niagara being converted?

In short, why is the transmission of power in almost every case where flexibility, convenience, economy, efficiency and reliability are required depending upon the electric method, not only in new work, but oftentimes to the replacing of older plants.

The elevator field, indeed, is a large one, and if the system is electric, then, considered from a commercial standpoint, there appears the following possible classes of work:

1st. High speed passenger service where no hydraulic plant is possible because of limited space.

2d. High speed passenger service in competition with hydraulic plants, the electric plant doing equal duty, costing less, occupying less space than the hydraulic, and costing much less to operate.

3d. Substitution of new high-speed electric service in place of old steam and slow hydraulic services in buildings where the limited space and interference with operations will not permit consideration of a new hydraulic plant.

4th. Passenger elevator service in buildings where the loads are comparatively light.

5th. Passenger service in private houses where safety, simplicity and noiselessness are essential.

6th. Freight and special classes of work.

For convenience we may classify elevator work as "first-class, that requiring speeds from 300′ to 600′ a minute," including the first three duties above mentioned, and as "second class, those requiring speeds of from 50′ to 250′ a minute," which include the remainder.

In general, there has been required and developed two kinds of machines to perform these services. The first is the outcome of the increased height of buildings and the demand for high speed and smooth motion, largely regardless of cost of apparatus, space occupied, or cost of operation.

The hydraulic elevator was the result of this demand, and was the only one that up to a year or so ago was accepted for this service.

It was to meet this demand—by creating an electric elevator which would do the work equally well, if not better, than the hydraulic—that the elevator to be more specifically described, was developed under some unexpected difficulties.

Of course, such a machine must have the speed and capacity of the hydraulic elevator.

It must be absolutely safe.

It should have advantages in the matter of space, and must be more economical to operate.

The second class of elevator work, that which requires lower speeds, is applied to small apartment houses and other buildings where lighter elevator duty is required. This, for a long time, has been fairly supplied by worm gear elevators, and the replacing of

the steam engine by an electric motor has enormously broadened the field for this class of machine.

These two machines, however, are not equivalents. They present two distinct kinds of rope movement, two absolutely different methods of control, and two varieties of safeties.

Just here I will briefly outline some of these differences, for they constitute in my mind vital essentials, and are absolutely determinate in their limitations.

The rope movement on the hydraulic is provided by an expanding set of sheaves on which all the ropes are maintained in fixed planes. Four to six ropes can be used on the machine, and six to eight on the car.

The sets of rope can be equalized at the machine, and they have a fixed lead in the hoistway.

The machines can be double and treble decked, and they have absolute limits of mechanical travel.

All of these features are of the greatest importance when dealing with high lifts, large powers and fast travel.

The drum machine, while having a distinct field of its own, and a most useful one, has not a single one of the characteristics mentioned. It cannot well use over two ropes on the drum, and they cannot be equalized at the machine. The lead is a shifting one, and on long lifts this may be as much as from four to five feet.

These particular objections have been met in a type of machine which may be called a cable drum machine, where the drive is by friction of the rope in the sheave grooves, but in both these machines, the plain drum and the cable drum, there is the very grave objection that there are no fixed limits of mechanical travel which are independent of the armature movement, and on fast speeds particularly, this is absolutely essential.

In the drum machines the driving power is applied through one or more worm gears.

In my own practice on light service, such as house automatic machines, and a low class of freight work, I use a single gear with double ball thrust bearings, and on heavier work, a right and left handed gear generally cut on the Hindley form, to give the fullest amount of gear surface, and with the shafts connected by independent machine-cut spur gearing, which allows the worm gears to be free from each other.

There is another distinction—that of control.

The hydraulic machine is necessarily a gravity machine, using power only in hoisting, its speed on the down side being controlled

by the rate of water exit. The machine is, of course, under counter-weighted.

In the drum machine, when there is any attempt at economy, over counter-weighting is generally used, part from the car and part from the back of the drum, the over counter-weighting being approximately equal to the average load.

With these two types of apparatus as precedents, the problem was: How far can electricity be applied? What are the limitations of control? What the conditions of installation and operation, and to what extent could one type be eliminated?

And the answer is: Both types must be used, but for distinct classes of service.

Taking the drum type and considering electrical control on a machine over-balanced for average service, the load up or down is sometimes with and sometimes against the machine. To control such a machine directly from a supply circuit (and I cannot seriously consider any other, no matter how ingenious or refined, as meeting general conditions), there is one method only, and that is the use of a rheostat in starting, and the inverse variation of the strength of the shunt field for about a two to one variation in speed. A cumulative series coil is only permissible in starting if variations of speeds are controllable, and in any event these variations are limited. Such a machine is, however, the best for second-class service.

Every one is familiar, of course, with the conditions of ordinary freight work. I might, however, here point out an important branch of this industry, and one which is destined for very wide application, and that is automatic house service, the machine to be controlled without an operator, and so installed as to be as safe as a stairway.

Briefly, such a machine, on my system of working, is equipped with an interlocking switch device on the machine, having a co-ordinating movement with it, and with the controlling circuit in series with a number of door switches automatically opened or closed with the doors. The doors themselves are fitted with mechanical locks, allowing a car to be opened only during a range of movement from 6″ above to 6″ below.

At each floor is a single controlling button. If the machine is at rest, the pressing of a button calls the car, wherever it may be, to the particular floor at which it is wanted, where it automatically stops. When the door is open it cannot be started, and when running, no one else can call it from the floor for which it is destined.

The machine also has an additional control in the car, and the safeguards attending its operation are such as to make it safe for servant, nurse, child or invalid.

The development of the multiple screw elevator was undertaken for the express purpose of supplanting in a large way the former standard for high duty office service, and although not by any means an easy problem, either electrically or mechanically, a knowledge of what the hydraulic elevator is and the variation of the types existing, gave adequate reasons for its attempt.

Let us consider for a moment a hydraulic system, and institute a few comparisons.

It consists primarily of a steam cylinder, or a multiplicity of steam cylinders, working ordinarily under poor conditions of steam economy, that is with a fixed cut-off in the high pressure cylinder of a compound pump or no cut-off in any cylinder of a simple pump. This element corresponds to the cylinders of a steam engine in the electric system, which use steam expansively with a cut-off varying according to the load, and under pressure conditions which are somewhat better than exist in a pump. It is to duplicate the results of this system of variable cut-offs and steam expansion, that the energies of the various pump builders have been more or less ineffectually bent for a great many years in plain acknowledgment of that defect in their simple and duplex pumps, the latter of which is common to almost every hydraulic plant of any size in the United States.

It is true that a so-called "high duty" pump with equalizing piston is used on some of the larger elevator plants, but its use has not proven by any means entirely successful, because of the spasmodic nature of the service.

Among the high duty pumps, the flywheel type, such as is used on large water pumping stations has been attempted, but rarely, I may fairly say, with success.

The next element is the water cylinder, which corresponds to the dynamo in the electric system, and on account of the high friction due to the packing, the efficiency of a water cylinder with its valves is not ordinarily equal to that of a dynamo, which with a motor stands to-day the typical example of an efficient energy converter.

The next element is the piping and the tanks, compression or roof, and perhaps an accumulator, into or through which the water is pumped for delivery to the controlling valves of the elevator, and that which corresponds to this in the electric system is its

simple wiring, and if a storage battery is used, then this last in conjunction with it.

Any competent engineer knows that, measured by standard practice, a given number of pounds of energy can be delivered to the controlling apparatus of an electric elevator for less pounds of steam, that is, water evaporated, through the medium of no less than fifty combinations of engines and dynamos, than can be delivered to the valves of any hydraulic cylinder through the standard pumps permissible in average elevator service. To be specific, the average water evaporation on a compound duplex pump, which is almost universally used, will in practice, be not less than about 60 to 70 pounds per horse-power of water energy delivered to the controlling valves, whereas the electric combination will easily give the same for less than 40 pounds.

There are exceptional conditions in which a higher economy can be gotten in a hydraulic system, but they are few and are not typical, and under equal conditions the steam consumption in an electric system can be cut in two.

But this is not all. The fact is persistently ignored, although the attempt is made to offset it by recent experiments with a differential piston, that a standard hydraulic elevator uses the same amount of water under the same pressure for every foot of travel of a car, which volume of water and pressure are determined by the maximum load which has to be carried, although the average load on the ropes, including the excess of car over counter-weight is not over one-third of the maximum. On the other hand, the electric elevator uses, and must use, under normal conditions, current directly proportional to the work, modified in a small degree by starting and slow running.

In short, over and above the friction load of the generating system, the steam consumption in the engines and the generation of electricity in the dynamo vary with the demand of the elevator machines. It is a system which is of necessity automatic.

On the other hand, the hydraulic system is one of the most flagrant violators of the relation which should exist between demand and supply. It is a system of transmission by water, having at one end a generating plant doing full duty for every foot of travel of its piston, with a variable duty on an elevator car at the other end, and an intermediate straight line water engine with its pipes and tanks taking care of that variable duty and using the balance of its energy in heating the water which passes through its valves.

Lack of economy, however, is not the only objection to the hy-

draulic system when looked at from the architect's or builder's standpoint. Until recent developments, these have always been strictly handicapped, not so much perhaps in the matter of cost, but in the internal arrangements of the building as well as in the lay-out of the basement, neither of which could be finally and satisfactorily, if even then, determined, until the particular type of machine had been accepted by the owner, and the contract finally made for it.

Nor has there been either singleness of design or unity of plan of operation. Each maker has had his own form of construction, his special method of control. Every building has brought up a problem more or less new, or at least conditions which had to be seriously considered in determining the elevator service. Horizontal and vertical machines, in basement or shaft; high or low multiplications; long and short, single and jointed cylinders; big and little diameters; large and small sheaves; free and suspended counter-weights; pulling and pushing machines; direct and differential pistons; roof tanks, stand pipes, accumulators and compression tanks; high and low pressures; hand rope, wheel or pilot-valve control; simple or compound pumps—all have made a nightmare of complications, giving more initial and continuing source of complaint and dispute than all the other engineering problems in a building.

So what more natural than that they should turn to electricity for emancipation? And this tendency is augmented by other reasons.

Leaving out central station supply, always, when properly equipped, to be preferred when the electric service is of a spasmodic or limited character, and considering for the present those large plants which characterize the modern office or hotel building and in a way rival central stations, every engineer knows that the fewer the number of well-proportioned units, the more alike they are, the freer the interchangeability between themselves, and the greater the extent to which any one unit can be utilized, the better the system for power generation and conversion, no matter what its character.

The best modern practice makes a three-unit direct-connected engine and dynamo plant the best for lighting a building. There is an empirical relation existing between the number of lights required in a building as ordinarily designed, and the elevator service. When, in addition to the lighting service, such a building adopts electric elevators, it is not now necessary that it shall add an independent generating plant.

All that is required is that the three units should be somewhat increased in size and, perhaps, one of them preferably divided, the mains all taken to a common switchboard with two-way switches, and every engine and dynamo thus made interchangeable on either the lighting or elevator circuits, and at times both, especially if using a slow acting corrective converter, some of each can be run from the same engine and dynamo. So, instead of five or six units, some water and some electric, the entire generating plant is reduced to a single system consisting of three units of one size, or two of that size and two of a half size, which can be run interchangeably, and one of which is almost always in reserve.

Just here it is well to consider the probable application of the storage battery which, if built with plenty of lead, with large surfaces and for heavy momentary discharges rather than for long time steady discharges, will prove a most important adjunct to elevator service, which, like railway work, is spasmodic in character.

A modern office electric elevator on actual average service requires an expenditure of about one kilowatt hour per car mile of travel for every eight or ten feet of platform area. A car will make from 1½ to 2½ miles per hour, so that a battery of six elevators will run from 9 to 15 miles, although very rarely making over 12 miles per hour. With an ordinary car, say from 30′ to 35′ area, this would mean from 3 to 3½ kilowatt hours per car mile of travel, or say 35 to 40 kilowatt hours for a battery of six machines. Without a battery this would require a 120 kilowatt machine as ordinarily rated, worked at an average of 35 to 40 per cent. load. With a properly constructed battery a 60 or even a 50 kilowatt machine will handle the elevators.

Roughly speaking, a storage battery should be able to stand twice the dynamo rate for from three, to seven or eight seconds, and the dynamo rate for one-half a minute. If it has an hour discharge capacity equal to the dynamo capacity in kilowatt hours, it should be perfectly capable to run the Saturday, Sunday and night service required in an elevator plant without losing more than one-half its charge.

So much for the general conclusions on electric elevators, which are necessarily more or less brief.

To meet the hydraulic machine there was designed and developed what is now known as the Sprague-Pratt multiple sheave electric screw elevator, following the general lines of a tension hydraulic machine in the matter of rope movement, limit safeties and method of control.

The net result has been, that this machine now stands the superior to the hydraulic elevator in that it has its speed and capacity with, if anything, greater safety, and certain advantages in its automatics.

On high lifts it occupies less space; it is more flexible in its application, is more economical to operate, and it is more easily cared for.

General Description.—The machine may be described as the combination of two old elements with one new one, with specific safeties and methods of control.

Briefly, it is of the horizontal multiple sheave type, with a traveling crosshead and frictionless nut driven by a screw revolved by a motor directly connected, and governed by a pilot motor and rheostat.

The general construction consists of a heavy main beam, carrying the traveling crosshead and the lower screw bearing, with special castings bolted at each end, one carrying the fixed set of sheaves, and the other the thrust bearing, brake and motor. The regulating apparatus is independent and self-contained, and is placed on the wall. From the car to the system of multiplying sheaves the direct multiplying machine and the horizontal hydraulic elevator are practically the same. The crosshead, however, marks the point of departure in the two types.

In the hydraulic machine, this crosshead is rigidly attached to the end of a rod which terminates in a piston moving in a cylinder having an inside length equal to the lineal movement of the crosshead. This cylinder in the vertical type of hydraulics varies from 30 to 50 feet in length, with from 2 to 12 sheave multiplications, and in the horizontal types the multiplication runs as high as 14, with corresponding diminution of length of cylinder and increase in cross-section. Whatever the gearing, however, the length of cylinder is a function of the car travel. In this electric elevator, the crosshead being moved along a screw, stationary so far as the lineal movement is concerned, there is, with any given number of sheaves—only one variable—the length of screw; and, for all heights above about 100 feet, the electric machine has an advantage in matter of length, which, with increased rises, becomes of great importance.

Looking to the needs of office buildings, there has been adopted two methods of rope multiplication, determined by the height of building, and so selected that the length of machine over all, shall not exceed about 30 feet for rises approaching 300 feet actual car

travel. From this the length grades down to about 21 feet, so that all rises between 60 and 300 feet can be taken care of with an extreme variation of nine or ten feet in the length of machine, and there is thus provided limiting dimension data of great convenience and utility.

These systems of multiplication I may term direct and indirect. In the former, the entire multiplication, varying from six to ten, is done at the machine, and the ropes lead from the end sheaves over the shaft sheaves direct to the car. A free counter-weight is used, the ropes being fastened to the car frame. In this method, which is that common to all horizontal and to many vertical hydraulic machines, the hoisting and counter-weight ropes have unequal duty; furthermore, the ropes having the maximum bending, travel on the outboard sheaves at the same speed as the car. This last is the case also with all vertical hydraulics. In some of the latter, the counter-weight is carried in the cylinder on the piston, or in the strap, or both, its weight being as many times that of a free counter-weight as there are multiplications. Sometimes both methods are used.

Economy of operation and smoothness of movement, however, are antagonistic in their relations to the amount of counter-weight carried. The best method is probably that used when there is a single multiplication in the shaft, giving a two to one counter-weight traveling at half speed, and carried by all the car-hoisting ropes, as is done for short-rise vertical hydraulic elevators.

For long rises I have adopted a combination vertical and horizontal machine rope practice, giving even a more compact machine, a longer life of ropes, and better counter-weight results.

In this indirect system there is a division of multiplication, which, while having the same effect so far as speed of car and length of machine are concerned as a high direct multiplication, has an entirely different result in the wear on the ropes and the amount of counter-weight which can be carried without jumping.

This is accomplished by making one-half the multiplication (6 or 8) on the machine, the ropes, properly proportioned, going thence to the bottom of the counter-weight frame, which has a single multiplying sheave on top. The car ropes go over the shaft sheaves, under the counter-weight multiplier, and back up the hoistway, where they are anchored, giving a car speed twice that of the counter-weight. The equalizing chains, used to make the pull of the car with any given load constant at all points of the hoistway, are fastened to the bottom of the counter-weight frame and anchored in the hoistway.

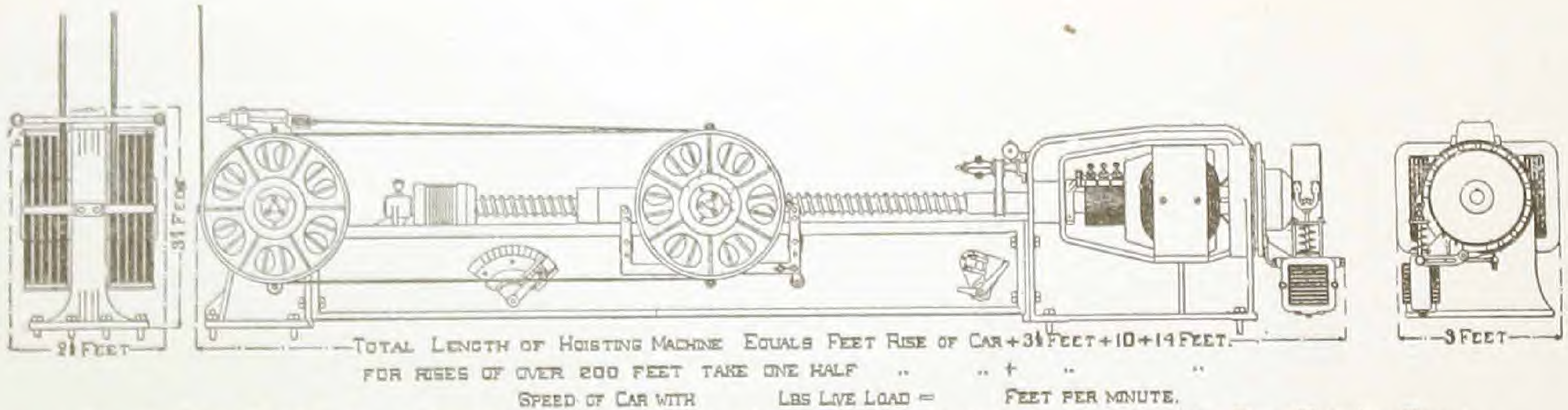

Fig. 1.—Type E, 10 to 1 — 4 R. 10 to 1 = Travel Ratio of Car to Nut = 10 Sheaves. 4 R Signifies Four Hoisting Ropes.

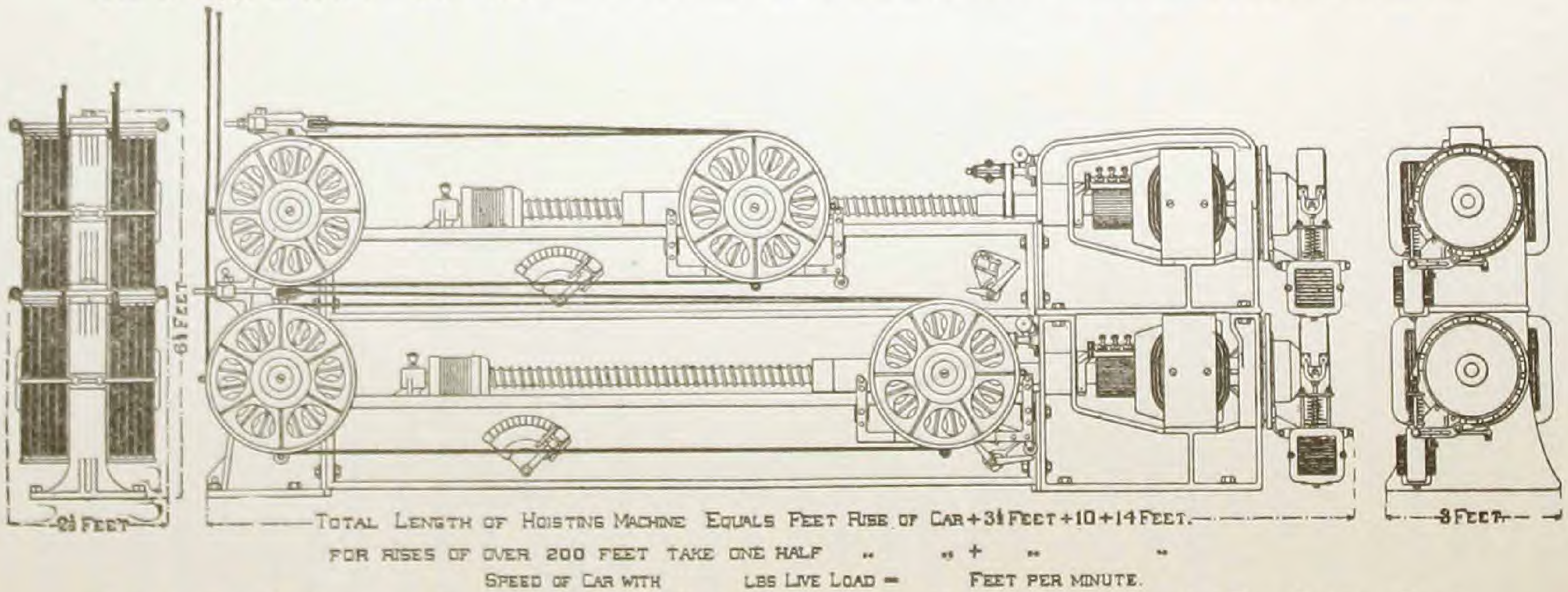

Fig. 2.—Type F, 10 to 1 — 4 R. 10 to 1 = Travel Ratio of car to Nut = 10 Sheaves. 4 R Signifies Four Hoisting Ropes

The space occupied by this multiplier is only two or three inches more than by ordinary form of counter-weight. A proportionally shorter screw, fewer revolutions, and sheaves of greater diameter, characterize this type of multiplying machine.

This system seems to be the best yet devised for long rises, for not only do all the car ropes do equal duty, both with relation to the hoisting strain and the counter-weight, but the rope wear must be less because of the division of speed and multiplication, the necessity of changing only one-half of the ropes at a time, and the possibility of reversal of the ropes on the multiplying machine to get a new wear.

Where space is limited, I use a double decked machine, and in the new Commercial Cable Building, which is to be 21 stories high, the machines will be treble decked, and about 10½ feet in height.

Details.—Turning now to the detail construction and operation of this machine, there are a number of features claiming special attention, each unique in character, and marking a radical departure from all other elevator practice. These are the nut, screw, and thrust bearing, the brake, the motor and the regulator apparatus.

One of the most interesting as well as important features, and, perhaps, the one which has been most frequently attacked, is the nut system. It joins the crosshead of the traveling sheaves by a conical seat. There is no fastening between the nut and the crosshead, the continual weight of the car always keeping them in contact; and the friction at this point, being greater than between the nut and the screw, enables the latter to transmit a straight-line movement to the crosshead when the screw is revolved by the motor, and also to revolve the screw and drive the motor as a dynamo when the mechanical brake releases the screw to allow the car to descend. These are the normal functions of hoisting and lowering. There are several other distinct functions of this nut which will be described in considering the "safeties."

Continuing the line of transmission of power, the only points of contact between the interlocking nut and screw are by a chain of balls which occupy a number of threads, and enter and leave the ends of the nut through tubes which are connected together so as to make a continuous conduit. This is one of the most vital points of the elevator apparatus, and herein lies one of the most potent reasons of its success—the reduction of friction by rolling instead of sliding surfaces on almost all parts under pressure, for not only is the nut so constituted, being in fact a developed spiral thrust-bearing, but the thrust-bearing at the motor end of the screw

is taken on balls and the sheaves are carried on ball or roller bearings.

This nut being a vital part, its development has been most thorough, and a peculiar treatment of steel which has been adopted renders its surface so hard that the wear is very small, and it is well within commercial limits.

So free is the machine from static friction that it is possible to start the car with a very slight increase of current over the normal hoisting current, providing time be taken so that the work done in acceleration is small to the work of lifting, although that is not the usual practice.

The balls have an average crushing strain of 25,000 pounds each, but the working pressure varies from only 50 to 125 pounds per ball.

The nut system is a compound one, for, besides the working-ball nut there is another, called the "safety-nut," to which I will make reference later, keyed to it, and between the two is a powerful spring under compression.

The screw is a forged bar of high carbon steel with a peculiarly shaped thread, the finished screw having a tensile strength of 700,000 pounds. It passes through the clearance hold in the steel trunnion crosshead, which carries the traveling sheaves, then through the nut, and is carried at the outer end by a fixed bearing.

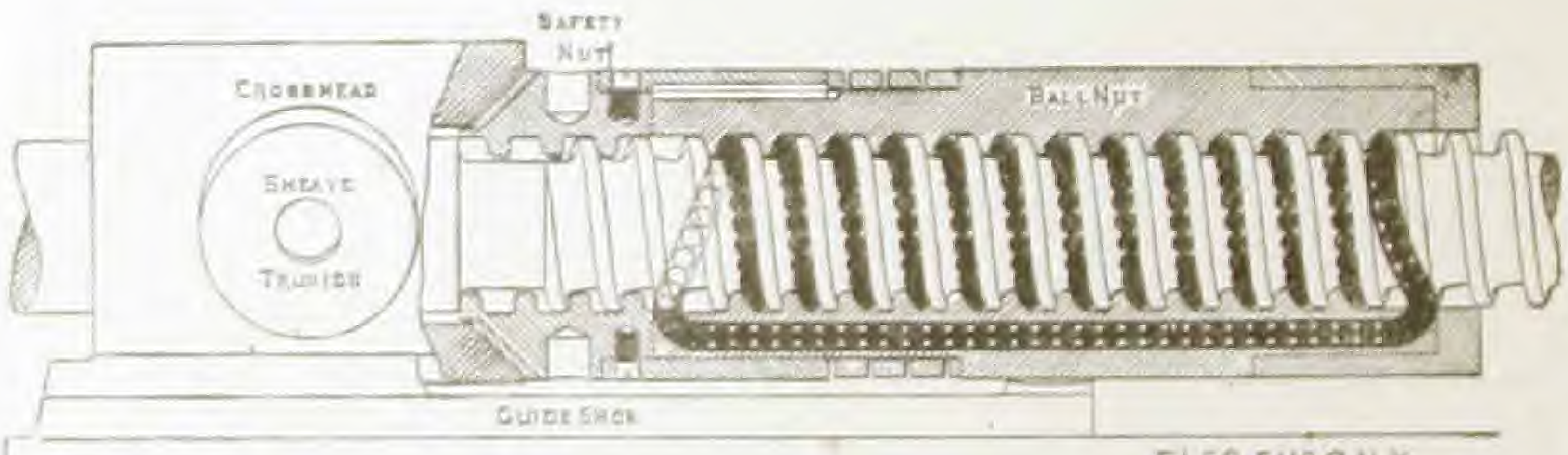

Fig. 3.

This screw is sectioned, being joined to the armature shaft by a cone-seated coupling, secured by a taper gib.

The in-board end of the armature shaft, which is in effect, the extension of the screw, terminates in the thrust-bearing, where the pressure is taken by about 200 steel balls carried in a bronze guide plate and bearing, by specially hardened steel disks. The thrust of the screw being thus taken up on the in-board end, the strain on the screw is invariably between that end and the traveling crosshead—never beyond this; hence, it is always under extension strain—never under compression, and cannot buckle.

The action of the balls on the screw, which is untreated, is

peculiar. They form a path for themselves, partly by wear, but principally by rolling compression of the steel, which finally becomes exceedingly hard, such that the edge of any ordinary machine tool would be turned.

The balls themselves wear very evenly. Oblique forms in normal practice cannot exist.

Beyond the thrust-plates is keyed an iron pulley, connected by a flexible coupling with the motor shaft. The function of the brake is that of locking the screw when at rest, it is not a means of varying the speed. In case of accident, it has the additional function of helping to stop the screw. It may be described as a compound electro-mechanical brake. A steel brake band, wood-lined, is anchored at one end, the hoisting-side on the motor-bed frame, and the other end is continually pulled down by a powerful spring under compression. The mechanical movement in opposition is through the medium of a peculiar magnet. It is operated by a dual circuit, one in hoisting, another in lowering. In the event of failure of current for any reason, or too high a speed on the down run, this magnet releases the brake in the latter case by a snap switch, operated by an adjustable Pickering centrifugal governor driven by the main screw—and the brake band promptly grips the brake wheel softly yet powerfully.

Motor.—The motor, which is of the multipolar type, is carried on the same casting which contains the thrust bearing. The field magnets are of steel, and are excited by two circuits; one, known as the shunt circuit, being variable in strength at will, so as to vary the maximum speed of the machine, and the other, a series circuit, which acts to strongly compound the field. This type of elevators is differentiated from all other electrics by the fact that the action is like that of the hydraulic, for it always works against gravity. In hoisting, the motor takes current from the line, but in lowering, its main circuit is cut off from the line, and the motor, rotating in an opposite direction, is driven as a dynamo by the weight of the car. A strong element of safety exists in the fact that the current in the field coils is never reversed, and consequently the machine is never demagnetized. Hence, under certain conditions of the operation of the safeties, it has a power of self-excitation which is of importance.

The armature which turns in this field is of the ironclad type, and not liable to injury of any kind.

It is mounted on a sleeve, is of the 2-path series winding, has a very large commutator, and, of course, multiple carbon brushes.

The field coils can be removed without disturbing any other part.

Control.—Considered in its simplest form, and in connection with its action upon the motor and multiplying machine, without reference to the means of communication between the car and the regulator, this last is a very simple device. It is composed of two parts, each made up of peculiarly shaped iron grids of various sizes arranged in circular form, connected to copper contacts on a slate disk over which passes a heavy carbon brush.

The use of iron castings of a specific composition possesses great advantage over any form of wire resistance, not alone in the matter of cost. They are flexible, they expand in any direction readily, and, as made, they have a resistance of from forty to fifty times that of copper, or roughly, that of German silver. The grids are interchangeable, and any of them can be readily replaced.

One side of the rheostat is for regulation in hoisting, the other for lowering. Instead of moving this regulator by hand, it is operated by a pilot motor wound with a right and left handed field, one or the other of which only at a time, can be in circuit with the armature. This pilot is connected to the rheostat arm by a single reduction worm gear, and is operated either from the basement or the car, according to the position of the "change over" switch, by an "up" and "down" button with an automatic lever stop which normally has to be held by the operator to prevent the pilot returning to a stop position. The spindle of the rheostat arm operates switches co-ordinating in their movement, in turn controlling the magnetic make-and-break circuit switches, the down brake, and also the automatic stop lever switches which limit the pilot movement.

The use of magnetic switches instead of hand control switches not only removes the arcing from the face of the rheostat, but it gives the benefit of instantaneous cut-offs not possible by any other means of control.

This, on fast machines is of the utmost importance, and the practical application is that if a car is on the "up" motion, and an operator, because of carelessness or because of fright lets go his stop handle, the current is instantly cut off, the regulator following to stop, and the car is arrested in the shortest time practicable.

Assuming that the circuit is made for the up movement, it first meets with a resistance sufficient to about hold the car and lift the brake. This resistance is then gradually cut out, the torsional effort of the armature is increased, giving the car an upward move-

ment with an acceleration depending upon the rate of movement of the rheostat arm, and with a final velocity determined by the point at which the arm is stopped.

If, while hoisting, for any reason the current is cut off, the torsional effort ceases, the brake instantly comes into action and the car comes to rest.

In lowering, the brake is lifted by an independent circuit, but the armature is first short-circuited on itself, and becomes a most powerful dynamic brake. As the resistance in this circuit is increased, the car runs faster. When it approaches the lower limit of movement, an independent retarding circuit is established, and gradually reduces the resistance. This brings the car to the slowest movement.

The pilot movement regulation is, to my mind, an absolute necessity of fast passenger work; and its application, although at first attended with a number of annoying difficulties, is to-day by far the most reliable method of control known.

Safeties.—Of course, the vital question to be considered in any elevator system is that of safety. In that respect, I think, we are amply provided. Safeties may be considered under two heads:

First, those on the car, and second, those on the hoisting machine.

On the car we use a special centrifugal which is attached to the lower section of the car frame.

It consists of two long levers, short-fulcrumed at the sides of the car and operating clamping jaws which run in close proximity to the car rails, but normally out of contact with them. The inner ends of the levers overlap, and in action are pressed apart by a very powerful spring under compression. When out of action, these levers are drawn together, the spring is put under compression, and the system locked by a trigger. Near the trigger is a centrifugal governor, operated by a standing rope, which at a determined speed releases the trigger, frees the levers, and the safeties clamp the rails with a pressure of about 16 tons. This safety can be released from the inside of the car.

In the car, as has already been described, there is an automatic stop contact which operates to bring the regulator to the stop position and the car to rest in case the conductor removes his hand from the controller because of crowding, accident or carelessness.

On the hoisting machine there are a number of safeties. One which is perfectly apparent is due to the fact that the crosshead is moved by a screw with a heavy armature on the end of it, which is driven through the medium of a nut by a car of limited driving

capacity. The screw itself is of forged steel, under tension and torsion strains, with a safety factor of at least twenty to one.

The hoisting nut, as already described, is hardened by a specific process which makes its wear very limited. In addition to this, there is in the nut system what is called a "safety nut." Normally this is out of contact with the thread of the screw, but it is secured to the hoisting nut, and should any accident happen to the latter, breaking its hold on the screw, this safety nut, the threads of which interlock with the screw's threads to a greater depth than the thread of the hoisting nut, would then take the place of the hoisting nut and securely grip the screw. This would put the elevator out of operation because the friction between the nut and screw would be greater than the friction of the traveling crosshead, and it would act simply as a collar on the screw.

The nut system has in addition another function. Since the hoisting nut is only held from revolving by its friction against the crosshead, when the nut gets to the upper limit of its travel the safety nut meets a solid collar on the screw which stops its travel, causing it and the ball-bearing nut to revolve with the screw, without, however, necessarily stopping the motor, and leaving the traveling sheaves to be stopped simply by the weight of the car.

There is still another function performed by the nut system, that of a slack cable device. If for any reason the car in descending, when of course the nut is driven along by the screw, meets an obstruction, the pressure on the nut being instantly reduced, it recedes slightly, allowing the springs between it and the safety nut to expand, throwing the latter into back contact with the screw threads. The nut system then instantly grips the screw, revolves as a collar, and consequently acts as a check against any marked movement of the crosshead corresponding to a free fall of the car on the ropes.

Assuming, however, the condition of a perfectly free release from all operative safeties, there is a limit to the rate of revolution of the screw, and in any event there is a rubber buffer at its lower end which would cushion its stop so as to prevent any injury.

Besides the lower limit switch, which has already been mentioned, which puts an increasing retarding force on the motor, there is an upper limit switch for cutting off the current; this is a self-cleaning lock switch, operating in both directions, and moved by a roll on the crosshead. It cuts off the current in hoisting in the upper limit, and allows the brake to come on. On the reverse movement it is automatically closed.

I have already mentioned the governor on the machine, which

is called a "monitor centrifugal." This is for operating the brake when running too fast. In hydraulic elevators there is no speed-operated device in case of fast running except the centrifugal on the car, and this is frequently set so much above the normal speed on account of the annoyance of having it operated by a temporary excess, as oftentimes to be useless when actually required. The monitor centrifugal does not throw the machine out of operation, but simply slows it up to any desired speed, and then allows the operator to resume control.

The dynamic action of the machine is made use of in still another way by the introduction of an "automatic choking circuit" and switch operated by the same circuits governing the main brake.

It is in constant play and closes the circuit around the armature and its series coils through a rheostat under any of the following circumstances: At each stop from up or down; when running down fast enough to work centrifugal on the machine; on failure of the hoisting current, or on failure of the line current.

So positive is the control over the motor, no matter whether it be operating to hoist the car or retard it in going down, that the brake band can actually be removed and the car still controlled, and even with the brake in normal position the change from one position to another can be made so promptly that it will remain inactive.

Such is the machine which has been developed during the past three years, and whose first application in a large battery in the Postal Telegraph Building seems destined to have the same effect on the elevator industry that the plant at Richmond has had on the railway industry. It is only permitted to me, of course, to make the briefest allusion to this, but as illustrating in some degree the extent of this industry, buildings of from five to twenty-one stories in height are being equipped with batteries of from one to twenty-six machines of various types, and the business of a single company employing some two or three years ago a handful of men, now demands a constantly increasing force already numbering nearly five hundred.